HIGH RESOLUTION ION BEAM PROFILE MEASUREMENT SYSTEM

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Abstract

A high resolution system designed for easy and inexpensive profile of an incident beam on a charged target, in the ion implanter installed at the Ion Beam Laboratory of the Technological Nuclear Institute (ITN) in Lisbon, Portugal, is described. This system intended to be used offline and not during the implantation, is made of a circular aluminium disc with a curved slit which extends approximately from the centre of the disc to its periphery. The disc is attached to the ion implanter target, which is capable of rotating on its axis. A cooper wire, positioned behind the slit, intersects the beam and the electric current generated, proportional to the beam intensity, is measured. As the ion implanter is capable of scanning the beam over the target, the combination of vertical beam scanning with aluminium disc rotation allows the beam profile to be measured continuously in two dimensions.

This paper describes the system developed including the computer controlled positioning of the beam over the moving curved slit, the data acquisition, the beam profile representation, and shows experimental results obtained with an Argon beam.

INTRODUTION

Traditional beam profile monitors use a matrix of detectors like Faraday Cups. The objective of this work is to develop a high resolution system for measuring the profile of an ion beam in an ion implanter. Two systems are in general use to monitor the beam profile, wire scanners and scintillation screens [1-3]. Both systems have proven their functionality and are chosen depending on the needs of the particular application. Their basic principles are well known and can be found in [4]. A third technique also used is residual gas monitors with segmented residual gas ion detecting plates, that is based on a similar principle as wire scanners regarding the reconstruction of the profile from the measured data.

Another technique is scintillation screens, which operates very fast and at very high resolution in position. They offer a convenient way to image the beam profile. Being their functionality based on (iono) luminescence [5], the most sensitive screens are made crystals like SiO_2. Using this option, the changes on the ion beam parameters influences the relative intensity of the intrinsic and activated luminescence [5]. Since the light yield also decreases with operational time, this method does not provide absolute values for the beam current. Also the lifetime of these kinds of detectors is strongly limited at higher beam powers. In such cases tantalum foils are used to illustrate the beam profile.

Absorbing the beam power a profile-dependent heat-induced glow is visible. To minimize the structure-smoothening and image-broadening heat flux inside the foil, the foils are chosen to be very thin. Nevertheless, their resolution is distinctly lower than that of crystal based scintillators. More examples for this detection system can be found in [1-2].

Wire scanners offer a quasi-non-destructive way to measure the profile in absolute current values. Their resolution and measuring speed generally behave antiproportional and depend on the number of wires used for detection and the analyzing electronics. A reliable determination of the beam profile can only be achieved if the ion distribution in the beam is Gaussian-like or at least single-peaked with only moderate asymmetry.

Problems occur if one unknowingly samples a hollow beam or a beam with more than one maximum in the current distribution. Additional details about this detection system can be found in [3, 6].

The presented system scans the beam on the target, using an off line beam profile scheme.

SYSTEM DESCRIPTION

As part of the deceleration system developed for the ion implanter, a beam profile monitor system was build to measure the shape of the beam over the target and set the optimal parameters for the deceleration lens taking into account the desired target bias.

The system developed, shown in Figure 1a, is composed by an insulated metallic disc of 25 cm diameter, which will be used as target, and a copper wire.

The target disc is mechanically attached to the implanter target, so it has the same rotating movement. On this target disc, a 3 mm wide and 10 cm long slit gap with a curved shape was made. A 3 mm wide and 10 cm long copper wire is placed behind the gap. This wire is fixed to the chamber structure and is connected to a microammeter, as shown in Figure 1b.

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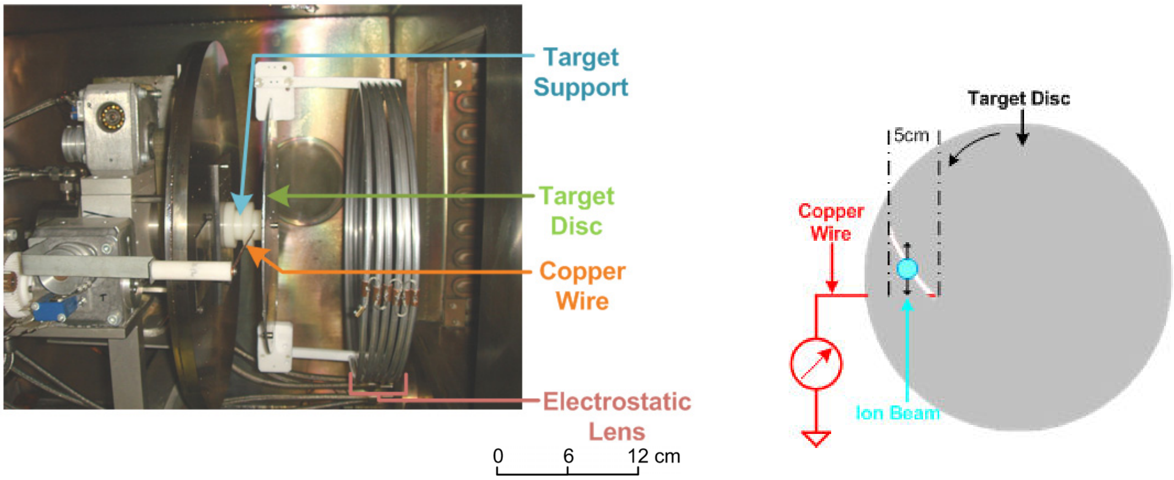


a) b)

Figure 1: a) Mechanical system implemented; b) Schematic system implemented.

According to Figure 2, when the beam hits the target disc, a small part of it hits the wire and creates an electron current which is measured.

Due to the slit gap shape and the fact that the wire is fixed, when the target disc rotates, the beam strikes different parts of the wire in a way that it scans the beam in an area of 3x3 mm^2, corresponding to the slit gap x wire width, over a 5 cm distance, as shown in Figure 1b.

With the wire fixed on the horizontal, a focused beam can be scanned by rotating the target with the slit gap crossing the beam. If the beam current measured on the wire is collected one gets a beam profile section in *x*. By scanning the beam in y using the implanter beam scanning systems one gets x and y profile of the beam.

The reason to use the beam scan in y and not in x is that the drift of the beam due to the target bias changes with the distance to the edge of the target, but has no significant change if that distance is maintained.

In order to obtain an ion beam profile, two signals are required, one proportional to the beam width (x-axes) and another proportional to the beam current (y-axes).The beam current can be defined as

$$I_{Beam} = \frac{V_A}{47M\Omega} \qquad (1)$$

Therefore, an optic-fiber based circuit was developed to send the beam current signal to the ground potential.

Whereas, on the resistance of 47 MΩ, the DC voltage proportional to the beam current is converted through a voltage-to-frequency (V/F), in a number of voltage pulses with a frequency proportional to its amplitude.

This signal is applied to an infrared LED connected to one side of an optic fiber. On the other side, placed at ground potential, a photo-transistor converts the light pulses to a number of voltage pulses with the original frequency. This signal is fed to a frequency-to-voltage (F/V) which is then digitized and goes to the personal computer (PC) as shown in Figure 2.

Figure 2 also shows the two high voltage (20 kV) power supplies used. One bias the lens (V_L) and the other bias the target (V_A). The resistances of 100 MΩ and 25 MΩ will allow a better stabilization of the voltage, avoiding any voltage fluctuations, while resistance of 47 MΩ is intended to measure the beam current.

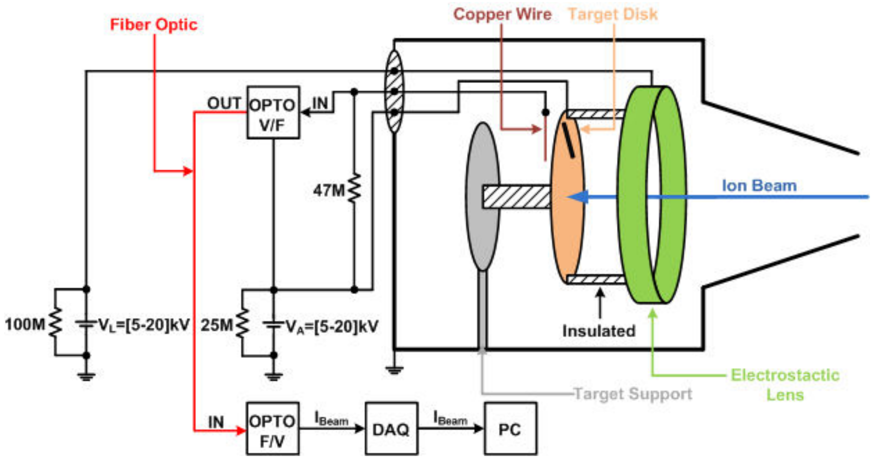


Figure 2: System developed.

A LabVIEW application was developed which controls the target position, gathers the digitized signals and determined the beam profile.

EXPERIMENTAL RESULTS

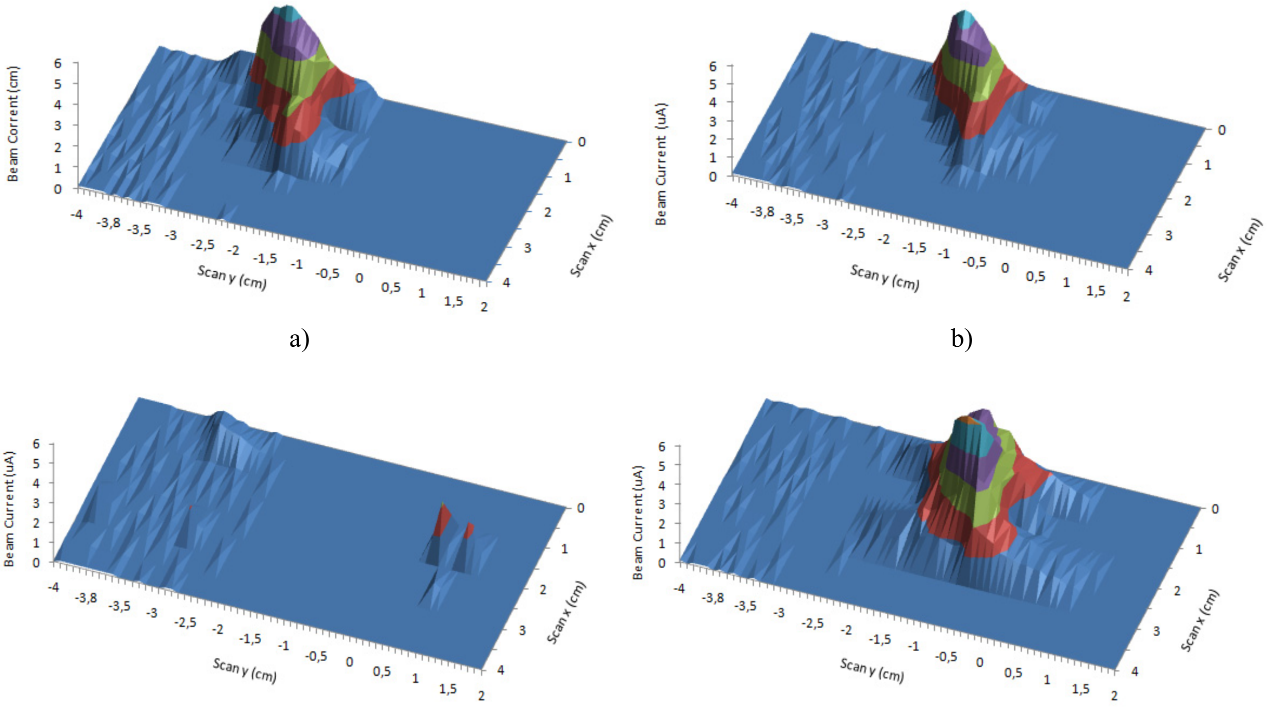
The system uses a personal computer equipped with a multifunction input/output board from National Instruments; model USB-6251. The program that was chosen for this work was National Instruments LabVIEW, a graphical programming language specially created for instrumentation and measurement, some custom made electronic interface modules and a LabVIEW application. Been integrated in a major project of the automation of the ion implanter, this is a part of the system that is considered as one of the most significant and that brings a great development and enhance to the ion implanter.

The ion beam profile measurement system developed makes integrant part of the optimization to the ion implantation, which also contemplates the deceleration of the ion beam to low energies. Checking the beam profile is important to guarantee that the implantations are successful even at low energies. In particular, as a result, it was possible to determine that the electrostatic deceleration developed for this accelerator is able to reduce the beam energy while maintaining the beam focused.

The experimental results presented in this work correspond to an ion implantation of Argon, with a beam current of 100 µA, initial energy of 15 keV.

The area of scan (x and y) is 5x7 cm^2, and the scan x corresponds to the rotational steps of the target. We made four experimental test: (1) with the target at 10 kV and the electrostatic lens with 0 kV (Figure 3a); (2) with the target with 10 kV and the electrostatic lens with 12 kV (Figure 3b), (3) with the target at 14 kV and the electrostatic lens with 0 kV (Figure 3c); (4) with the target at 14 kV and the electrostatic lens with 16 kV (Figure 3d). For the first and second test, the electrostatic lens is not charged, which means that ion beam is more scattered and less homogeneous. In the third and fourth test it is possible to see that the ion beam is more focused on the target. These two examples (Figures 3c and 3d), shows that the use of an electrostatic lens in this system gives an ion beam more focus and uniform.

In Figure 3d is possible to verify with more precision the effect of the electrostatic lens in the low energies (1 keV). In this case, the introduction of an electrostatic lens allows to obtain an ion beam more focused for low energies. When the electrostatic lens is not used, the ion beam is too disperse, which means that is not possible to proceed with the implantation for low energies (Figure 3c). Hence, the beam focus is directly related to the deceleration process, in order to obtain the desired final energy. This means that the bigger the deceleration level the more important is the beam focus.



a) b)

c) d)

Figure 3: Beam profile for: a) E=5 keV (Target=10 kV, Lens=0 kV); b) E=5 keV (Target=10 kV, Lens=12 kV); c) E=1 keV (Target=14 kV, Lens=0 kV); d) E=1 keV (Target=14kV, Lens=16 kV).

CONCLUSION

In this paper a high resolution system designed for measuring the ion beam profile in the ion implanter installed at the Ion Beam Laboratory of the Technological Nuclear Institute (ITN) was described. The low cost and simplicity is the Figure of merit of this system.

With the system developed it is possible to measure the beam profile and to compare the differences between ion implantation based on energy and beam focus.

Detectors were used in order to be able to visualize the beam profile, in the systems there was presented. This allows obtaining tridimensional pictures of the ion beam with ion currents in the range of μA, and energies from 10 keV up to a few hundreds keV. Comparing this system with others two major differences come up, the current range and the type of implantation.

In addition is possible to obtain data for deceleration, in the future, the system will allow to test new configurations for beam focus at lower energy.

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